The Importance of Belowground Plant Allocation for Terrestrial Carbon Sequestration

Margaret S. Torn, T.E. Dawson[1], J.A. Bird, J. Gaudinski, and D.E. Williard
[1]University of California, Berkeley
Contact: Margaret S. Torn, 510/495-2223, mstorn@lbl.gov

RESEARCH OBJECTIVES

One strategy proposed for sequestering carbon in terrestrial ecosystems is to increase allocation of carbon to roots, on the assumption that root inputs are efficiently converted to stable soil organic matter (SOM). We are conducting research to fill critical gaps in understanding belowground carbon cycling and sequestration in soils of temperate forests, by characterizing:

- The lifetime of fine roots and implications for belowground net primary productivity
- Decomposition dynamics of root and needle/leaf C inputs
- Total residence time of belowground C, including SOM

APPROACH

The total residence time of root C in the ecosystem depends on how long roots live, the decay rate of root litter, the fraction of C inputs humified rather than lost as CO_2, and the stability of decomposition products. We are characterizing these aspects of residence time with field experiments and isotope-based approaches, including: (1) Natural abundance ^{14}C to determine fine-root lifetimes; (2) Litterbags and *in situ* incubations of ^{13}C-labeled litter to estimate litter decay rates; (3) ^{13}C-labeled litter to track root and needle decay into soil-respired CO_2, microbial biomass, and soil organic fractions.

We are conducting the full suite of measurements at a mature ponderosa pine forest (Blodgett, California), measuring roots and litter decay at Harvard Forest, Massachusetts, and focusing on fine-root lifetime at additional forests in the U.S. and Europe. We report here the first year's results on litter decomposition.

ACCOMPLISHMENTS

Several lines of evidence indicate that roots decompose more slowly than leaves or needles in the first year of decay. First, the litter bags had greater mass loss of needles compared to roots at Blodgett (75% versus 90% mass remaining, respectively) and leaves compared to roots at Harvard Forest (65% versus 90% mass remaining, respectively). Second, for the ^{13}C-labeled litter, recovery of fine-root C exceeded that of needles (77% versus 52%, respectively). Third, after one year, more of the needle material had been reduced to a smaller size class (<2 mm) than had the roots (42% and 24%, respectively), see figure 1. Finally, the loss of C as respired CO_2 was greater for needles than for roots.

Decay rates may vary because of chemical quality or the depth of placement, with the latter affecting both microclimate and soil mineral composition. We saw little or no significant effect on decay rates between two depths (O and A horizons), for either the litter bag or the ^{13}C label experiments. In contrast, we did find a greater proportion of C compounds associated with recalcitrance, such as acid-soluble C and lignin, in roots compared to needles and leaves. Preliminary results suggest that chemical quality, rather than timing or depth of input to soil, was responsible for the differences in decay rates.

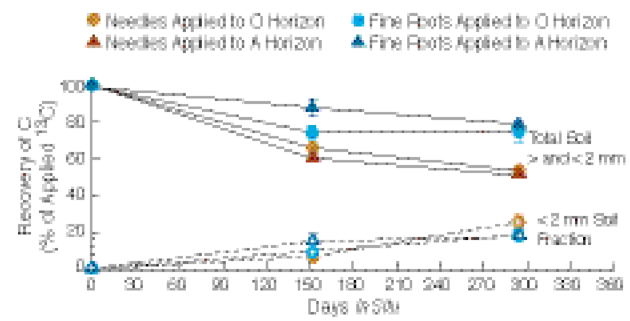

Figure 1. Percent C recovery from needle and root litter after 10 months *in situ*. Litter was applied to the top of the O horizon or 2–5 cm below the O/A interface in the A horizon during November 2001. Shown are total C recovery in the whole soil (solid lines) and the <2 mm fraction (dashed lines). Means (n = 4) and standard errors are shown.

SIGNIFICANCE OF FINDINGS

Although roots live longer and decay more slowly than leaves or needles in these temperate forests, estimating the long-term sequestration potential will require a second phase of research on the humification pathways and stabilization of root inputs.

RELATED PUBLICATION

Torn, M.S., S. Davis, J.A. Bird, M.R. Shaw, and M.E. Conrad, Automated analysis of $^{13}C/^{12}C$ ratios in CO_2 and dissolved inorganic carbon for ecological and environmental applications. Rapid Communications in Mass Spectrometry, 2003 (in press). Berkeley Lab Report LBNL-53147.

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